$C_{water} = 4.18 \frac{J}{g°C}$ $C_{ice} = 2.10 \frac{J}{g°C}$ $C_{steam} = 2.0 \frac{J}{g°C}$

$H_{vap} = 2260 \frac{kJ}{kg}$

Calorimetry and Specific Heat Calculation Worksheet

1. Find the equilibrium temperature if 200.0 grams of cold water at 10.0°C is mixed with 600.0 grams of warm water at 60.0°C.

47.5°C

$E_h = -E_h$

$mc\Delta T = mc\Delta T$

$(200g)(4.18 \frac{J}{g°C})(T_f - 10) = -(600g)(4.18 \frac{J}{g°C})(T_f - 60)$

$836T_f - 8360 = -2508T_f + 150480$

$T_f = 47.5°C$

2. 350 g of ice at 0.00°C are added to 50.0 g of steam at 140°C. Find T_f. ☆see page at back☆

12.5°C

s→l g→l

$E_{ice} = -E_{steam}$

$(349.26g)(335 \frac{J}{g}) + (349.25g)(4.18 \frac{J}{g°C})(T_f - 0) = -((50g)(2260 \frac{J}{g}) + (50g)(2.0 \frac{J}{g°C})(100-140) + (50g)(4.18 \frac{J}{g°C})(T_f - 100))$

$116998.75 + 1459.9T_f = -(-113000 + (-4000) + 209(T_f - 100))$

$116998.75 + 1459.9T_f = -(-117000 + 209T_f - 20900)$

$116998.75 + 1668.9T_f = 137900$

$T_f = 12.5°C$ 0.75g ice remains

3. A 600 ml sample of water is at 80.0°C. How many grams of ice at -20.0°C must be added to bring the temperature down to 5.00°C?

474g

-20°→0°C
$Q = mc\Delta T$
$= m(2.10)(0 - -20)$
$Q = 42m$

s→l
$Q = mH_f$
$= m(335 \frac{J}{g})$
$Q = 335m$

0→5°C
$Q = mc\Delta T$
$= m(4.18)(5-0)$
$Q = 20.9m$

$E_{ice} = -E_{water}$

$(42m + 335m + 20.9m) = -(600)(4.18)(5-80)$

$398m = 188100 \Rightarrow m = 474g$

4. An iron skillet weighing 1300 g is heated on a stove to 178°C. How many joules have to be removed in order for the skillet to cool to 21°C? (c_{Fe} = 0.449 J/g-°C)

$Q = mc\Delta T$

$= (1300g)(0.449 \frac{J}{g°C})(21 - 178°C)$

$9.16 \times 10^4 J$

$Q = -91640.9$

$Q = -9.16 \times 10^4 J$ (removed → negative)

5. When ice melts into liquid water at 0.0° C, it absorbs 0.334 kJ/g. Suppose the amount of heat needed to melt 38.0 g of ice is absorbed from 0.210 kg of water contained in a glass, at a temperature of 21.0°C. What is the final temperature of the water in the glass?

to melt 38g ice: $Q = mH_f = (38g)(335\frac{J}{g}) = 12730J$

$T_f = 5.5°C$

heat absorbed by ice = heat lost by water

$12730 + (38g)(4.18)(T_f - 0) = -(0.210kg)(4.18\frac{J}{g°C})(T_f - 21)$

$12730 + 158.84T_f = -877.8T_f + 18433.8$

$1036.64T_f = 5703.8 \quad T_f = 5.5°C$

6. A hot, 80.0-g iron spoon (T=95.0°C) is placed in a coffee cup containing 100.0 g of water at 20°C. After the spoon and the water reach thermal equilibrium, what is the temperature of the water? Use the following information: (CFe=0.45 J/g °C, Cw=4.184 J/g °C).

$-E_{h\ spoon} = E_{h\ water}$

$-mc\Delta T = mc\Delta T$

$-(80g)(0.45\frac{J}{g°C})(T_f - 95) = (100g)(4.184\frac{J}{g°C})(T_f - 20)$

$-36T_f + 3420 = 418.4T_f - 8368$

$11788 = 454.4T_f$

$T_f = 25.9°C$

7. A 400.0 g sample of methanol at 16.0°C is mixed with 400.0 g of water at 85.0°C. Assuming no heat loss to the surroundings, what is the final temperature of the mixture? The specific heat of methanol is 2450 J/kg•°C.

$E_{h\ meth} = -E_{h\ water}$

$mc\Delta T = -mc\Delta T$

$(400g)(2450\frac{J}{kg°C})(T_f - 16) = -(400g)(4.18\frac{J}{g°C})(T_f - 85)$

$980T_f - 15680 = -1672T_f + 142120$

$2652T_f = 157800$

$T_f = 59.5°C$

$\frac{0.5 kJ}{kg°C} = \frac{0.5 J}{g°C}$

8. A 1.0 kg sample of metal with a specific heat of 0.50 kJ/kg°C is heated to 100.0°C and then placed in a 50.0 g sample of water at 20.0°C. What is the final temperature of the metal and the water?

En water = − En metal

$mC\Delta T = -mC\Delta T$

$(50g)(4.18\frac{J}{g°C})(T_f - 20) = -(1kg)(0.5\frac{kJ}{kg°C})(T_f - 100)$

$209T_f - 4180 = -500T_f + 50000$

$709T_f = 54180$

$T_f = 76.4°C$

9. A 2.50 g sample of zinc is heated, then placed in a calorimeter containing 65.0 g of water. Temperature of water increases from 20.00°C to 22.50°C. The specific heat of zinc is 0.390 J/g°C. What was the initial temperature of the zinc metal sample?

En water = − En metal

$mC\Delta T = -mC\Delta T$

$(65g)(4.18\frac{J}{g°C})(22.50 - 20) = -(2.50)(0.390\frac{J}{g°C})(22.5 - T_i)$

$679.25 = -21.94 + 0.975T_i$

$T_i = 719°C$

10. A 13.5 g sample of gold is heated, then placed in a calorimeter containing 60.0 g of water. Temperature of water increases from 19.00°C to 20.00°C. The specific heat of gold is 0.130 J/g°C. What was the initial temperature of the gold metal sample?

En water = − En gold

$mC\Delta T = -mC\Delta T$

$(60g)(4.18\frac{J}{g°C})(20 - 19) = -(13.5g)(0.130\frac{J}{g°C})(20 - T_i)$

$250.8 = -35.1 + 1.755T_i$

$T_i = 163°C$

-16.4

11. A 28.4 g sample of aluminum is heated to 39.4°C, then is placed in a calorimeter containing 50.0 g of water. Temperature of water increases from 21.00°C to 23.00°C. What is the specific heat of aluminum?

$En_{water} = -En_{Aluminum}$

$mc\Delta T = -mc\Delta T$

$(50g)(4.18\frac{J}{g°C})(23-21) = -(28.4)\,c_{Al}(23-39.4)$

$c_{Al} = 0.897 \frac{J}{g°C}$

12. A 25.0g sample of an alloy was heated to 100°C and dropped into a beaker containing 90 grams of water at 25.32°C. The temperature of the water rose to a final temperature of 27.18°C. Neglecting heat losses to the room and the heat capacity of the beaker itself, what is the specific heat of the alloy?

$En_{water} = -En_{alloy}$

$mc\Delta T = -mc\Delta T$

$(90g)(4.18\frac{J}{g°C})(27.18-25.32) = -(25g)\,c_{alloy}(27.18-100)$

$699.73 = 1820.5\,c_{alloy}$

$c_{alloy} = 0.384 \frac{J}{g°C}$

13. Phileas Fogg, the character who went around the world in 80 days, was very fussy about his bathwater temperature. It had to be exactly 38.0° C. You are his butler, and one morning while checking his bath temperature, you notice that it's 42.0°C. You plan to cool the 100.0 kg of water to the desired temperature by adding an aluminum-duckie originally at freezer temperature (-24.0°C). Of what mass should the Al-duckie be? [Specific heat of Al = 0.900 J/(g°C); density of water =1 .00 g/ml]. Assume that no heat is lost to the air.

$-En_{water} = En_{Aluminum}$

$-mc\Delta T = mc\Delta T$

$-(100kg)(4.18\frac{J}{g°C})(38-42) = m\,(0.900\frac{J}{g°C})(38-(-24))$

$+1672000 = 55.8\,m$

$m = 29964\ g$

$m_{Al} = 30\ kg$

14. A hot cup of tea is often a beverage of choice in the winter because it warms us up. The temperature of the tea is 50.0°C and the normal body temperature is 37.2°C. If you drink a cup of tea with a mass of 256.3 grams, how much heat energy was transferred to your body? C of water = 4.184 J/gC°

$$Q = mc\Delta T$$
$$= (256.3g)\left(4.184\frac{J}{g^{\circ}C}\right)(37.2-50)$$
$$Q = -13726\ J$$

13726 J transferred to your body

15. You want to do an experiment to measure the conversion of gravitational potential energy to kinetic energy to heat by dropping 2.0 kg of copper off the roof of Churchill, a height of 14 m. How much will the temperature of the copper increase?

$C_{copper} = 0.386\frac{J}{g^{\circ}C}$

$$E_p = mgh$$
$$= (2kg)(9.8\,m/s^2)(14m)$$
$$E_p = 274.4\ J$$
$$Q = mc\Delta T$$
$$274.4 = (2kg)\left(0.386\frac{J}{g^{\circ}C}\right)\Delta T\left(\times 1000\frac{g}{kg}\right)$$

$\Delta T = 0.36\,^{\circ}C$

16. Based on your answer to question #15 above, you decide to modify your experiment by dropping the 2.0kg bag of copper from a height of 2.0m to the floor multiple times. How many times would you need to drop the copper bag to get a temperature increase of 2◦C?

$$Q = mc\Delta T$$
$$= (2.0kg)\left(0.386\frac{J}{g^{\circ}C}\right)\left(1000\frac{g}{kg}\right)(2^{\circ}C)$$
$$Q = 1544J$$

$$E_p = mg\Delta h$$
$$1544 = 2.0kg\,(9.8\,m/s^2)(2m \times n)$$
$$n = 39.4$$

↑ number of times dropped

n = 40 times

Calorimetry + Specific Heat Calculations

Q#2 Solution

$C_{steam} = 2.0 \frac{J}{g°C}$ $C_{ice} = 2.10 \frac{J}{g°C}$

$H_{vap} = 2260 \frac{kJ}{kg}$

$H_{fus} = 335 \frac{J}{g}$

Q_1 = energy required to melt ice

Q_2 = energy required to raise temp of melted ice from $0 \rightarrow T_f$

Q_3 = energy released from cooling steam from $140°C \rightarrow 100°C$

Q_4 = energy released from steam condensing

Q_5 = energy released from cooling condensed steam from $100°C \rightarrow T_f$

$Q_1 = mH_{fus} = (350g)(335\frac{J}{g}) = 117250 J$

$Q_2 = mc\Delta T = (350g)(4.18\frac{J}{g°C})(T_f - 0) = 1463T_f \ J$

$Q_3 = mc\Delta T = (50g)(2.0\frac{J}{g°C})(100-140) = 4000 J$

$Q_4 = mH_{vap} = (50g)(2260\frac{J}{g}) = 113000 J$

$Q_5 = mc\Delta T = (50g)(4.18\frac{J}{g°C})(T_f - 100) = (209T_f - 20900) J$

$Q_3 + Q_4 = 117000 J$

$Q_3 + Q_4 < Q_1 \Rightarrow$ not enough energy to melt all the ice.

How much ice can we melt?

We have 117000 J from steam cooling + condensing ($Q_3 + Q_4$)

$117000 = mH_f$

$117000 = (m)(335\frac{J}{g})$

$m = 349.25g \rightarrow$ so 0.75g of ice are left, 349.25g of water to heat.

$$E_{ice} = -E_{steam}$$

$$\overbrace{(349.25g)\left(335\frac{J}{g}\right)}^{s \to l} + \overbrace{(349.25g)\left(4.18\frac{J}{g°C}\right)(T_f - 0)}^{\text{heating melted water}}$$

$$= -\left(\overbrace{(50g)\left(2260\frac{J}{g}\right)}^{g \to l} + \overbrace{(50g)\left(2.0\frac{J}{g°C}\right)(100-140)}^{\text{cooling steam to 100°C}} + \underbrace{(50g)\left(4.18\frac{J}{g°C}\right)(T_f - 100)}_{\text{cooling condensed steam}}\right)$$

$$116998.75 + 1439.9T_f = -(-113000 + (-4000) + 209(T_f - 100))$$

$$116998.75 + 1439.9T_f = -(-117000 + 209T_f - 20900)$$

$$116998.75 + 1439.9T_f = 137900$$

$$\boxed{T_f = 12.5°C}$$

☆ 0.75g of ice remains